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(54) Subsea pipe protection and insulation

(57) Method and apparatus for reducing the rate of cooling of a seabed pipeline (4) when the flow of hot materials therein is reduced, wherein there is provided around the pipeline a heat-retaining material (2) adjacent the pipeline, and a heat-insulation material (1) around the heat-retaining material. The heat-insulation can be in the form of a concrete cover, for example, having a tunnel in its underside to receive the pipeline. Material (2) may comprise water, sea-water which may be polymerized, bitumen, wax or a thixotropic gel and the cover or material (1) may comprise concrete. The material (2) may be contained in a bag.

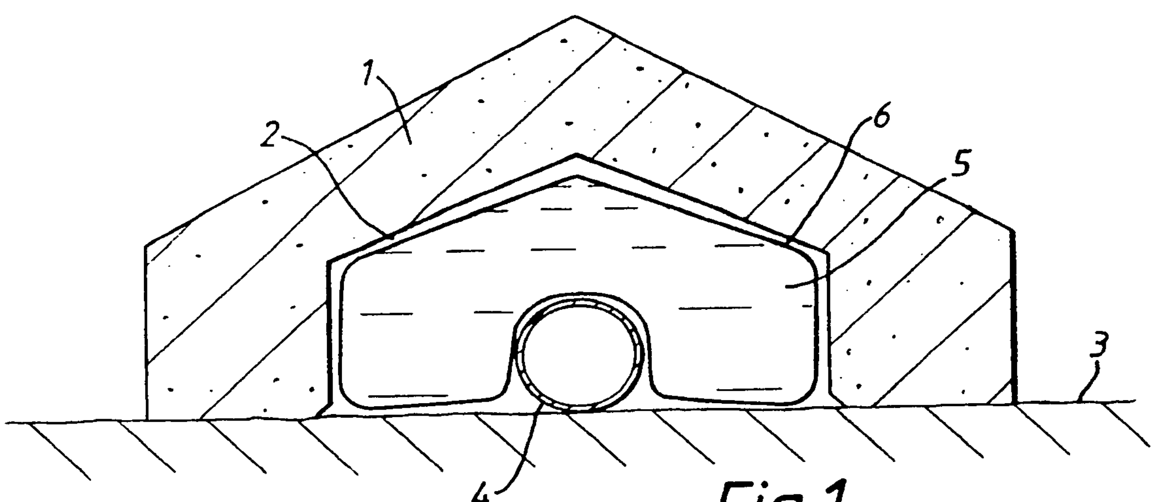

Fig.1.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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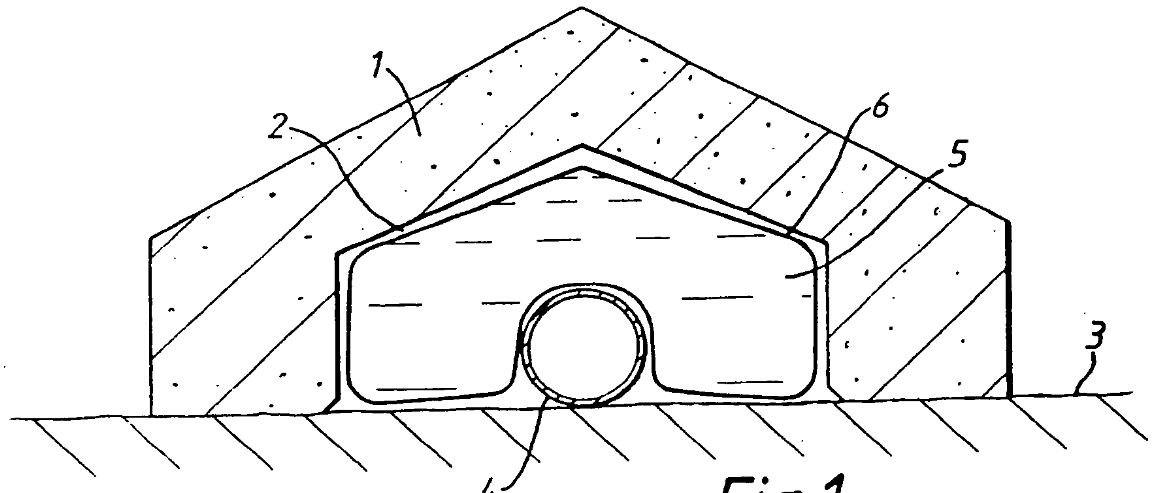

Fig.1.

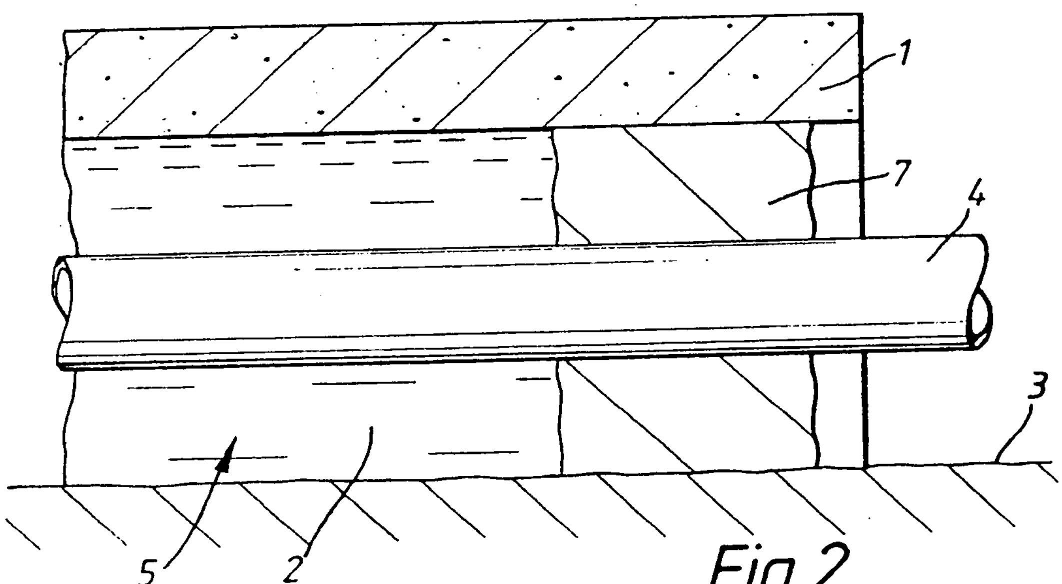

Fig.2.

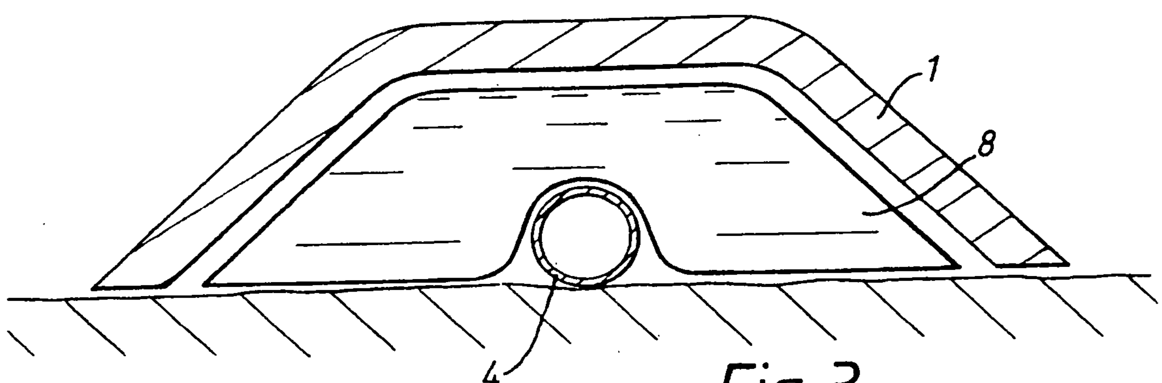

Fig.3.

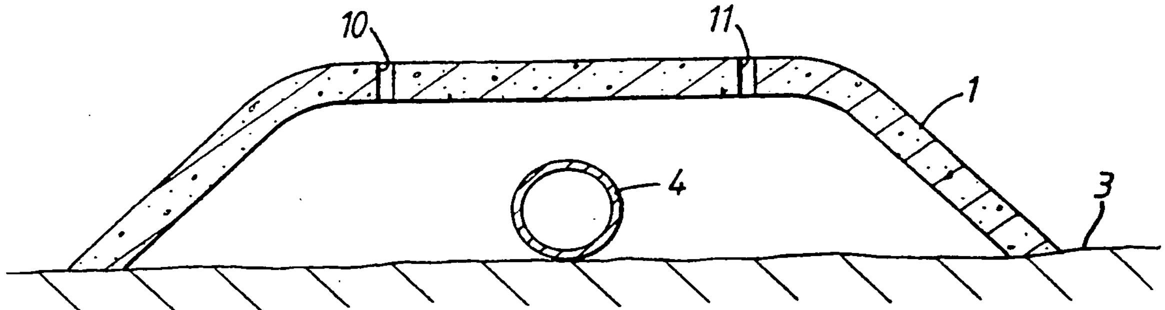

Fig.4A.

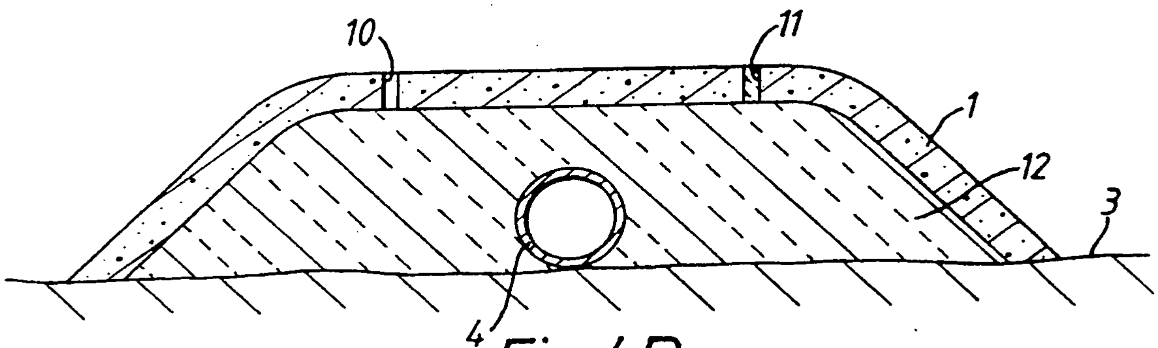

Fig.4B.

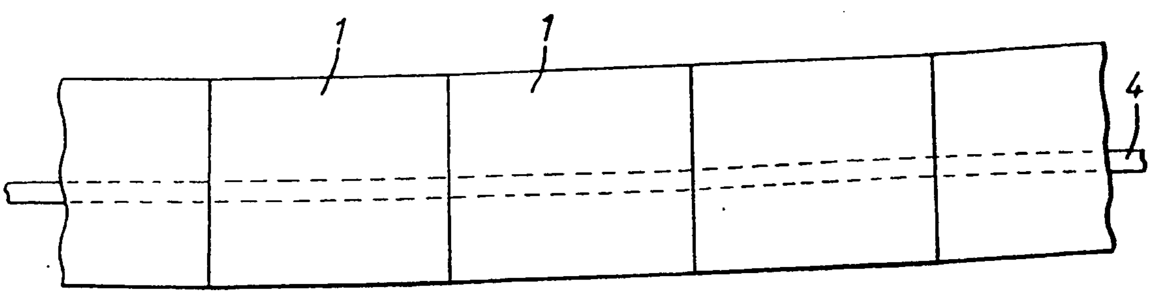

Fig.5.

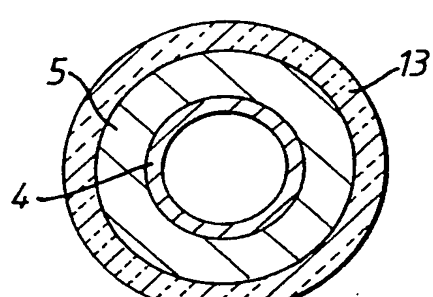

Fig.6.

SUBSEA PIPELINE PROTECTION

The present invention relates to a method and apparatus for reducing the rate of cooling of subsea pipelines.

The development of oil and gas reserves frequently calls for small diameter pipelines or flowlines to be laid on the seabed for transport of the produced fluids from the wellhead to a distant manifold or processing platform. The produced fluids frequently contain waxes and other hydrocarbon mixes such that if the temperature of the fluids drops to that approaching the ambient seawater temperature, there is formation of hydrates and/or solidification of the waxes such that the flow regime is either greatly impaired or actually stopped. Complex operational procedures such as pigging the line or providing some external heat source may be necessary to allow flow to recommence, and both of these techniques involve considerable disturbance to the production of the wellstream and may not be available particularly for remote wellheads which may be 10km or more from the processing platform.

Existing techniques aimed at resolving this problem involve extensive use of insulation materials. These can be applied on to the pipeline during manufacture generally as a thin film of a closed cell foam or similar insulant. Other materials such as polychloroprene (Neoprene) can be used either in conjunction with the foam

or independently. Polyurethanes and polyurethanes with glass microspheres to enhance insulation have also been used.

A further method of enhancing the insulation of the pipeline system is to dump a sand bund onto the flowline. The sand provides some additional insulation and is generally held in place by a gravel or rock covering.

Combinations of these techniques provide adequate insulation to maintain pipeline outlet temperatures above the critical levels, provided that the pipeline is kept flowing. Once the pipeline flow is stopped, however, it cools rapidly eg. in four hours or less, so allowing wax solidification and hydrate formation to take place. The normal operational procedure for such subsea pipelines is therefore to keep the pipeline flowing regardless of the status of other parts of the processing system by, for example, shutting down the platform wells. The consequence of shutdown of the subsea flowline for more than a short time is usually substantial loss of production.

We have now devised a way of providing a much longer flow shutdown in a subsea pipeline without risk of wax solidification and hydrate formation. Thus, we have found a way of elongating the permissible shutdown from one or two hours to 24 hours or longer, for example, in many cases.

In accordance with a feature of the present invention, instead of providing insulation around the pipeline to prevent heat loss therefrom, we allow heat loss during normal pipeline flow and the heat is absorbed by and stored in a heat-retaining material adjacent the pipeline. Thus, a heat store is provided around the pipeline so that, in the event of shutdown, the pipeline and its contents are kept warm by the heat stored in the heat-retaining material. In accordance with a further feature of the invention, the heat-retaining material is provided with heat-insulation to prevent or reduce heat-loss therefrom

outwardly into the surrounding environment.

Thus, in one aspect, the invention provides a method of reducing the rate of cooling of the contents of a subsea pipeline when flow therein is reduced, which comprises confining adjacent the pipeline a heat-retaining material selected from water, seawater, polymerised seawater, wax, bitumen, a thixotropic gel, and other materials having a specific heat capacity of at least 1.5J/°K.g, and providing a heat-insulation material outwardly of the heat-retaining material, the heat-insulation material being selected from concrete and other materials having a thermal conductivity of no more than 1.5W/mK.

The invention also includes a subsea installation which comprises a pipeline for flow of hot materials, a heat-retaining material confined adjacent the pipeline to receive heat therefrom in normal flow, and a heat-insulation material outwardly of the heat-retaining material to reduce heat loss therefrom to the surrounding environment, wherein said heat-retaining material is selected from water, seawater, polymerised seawater, wax, bitumen, a thixotropic gel, and other materials having a specific heat capacity of at least 1.5J/°K.g, and said heat-insulation material is selected from concrete and other materials having a thermal conductivity of no more than 1.5W/mK.

There are many ways in which the invention can be practised. For example, a heat-retaining material can be confined around a pipeline and an outer layer of heat-insulation material applied thereover. However, in many instances, it is desirable or necessary to provide subsea pipelines with protection against damage from, for example, falling objects, trawl boards etc., and also to provide some means of stabilising the pipelines on the seabed. These objects have been achieved to a greater or lesser extent in the past by either laying the pipeline in a trench or by covering it with a subsea mat or cover usually made of

concrete. The present invention can be practised very satisfactorily with either of these procedures. Thus, for example, heat-retaining material with insulant to prevent outward heat loss can be provided in the pipeline trench. However, the invention is particularly useful where subsea mats or covers are used. In such cases, the cover itself can provide the heat insulant. The invention will hereafter be described principally with reference to the use of covers, but it will be understood that the invention is generally of much broader application.

The use of a cover (or mattress), with heat retaining materials in combination can provide both a high level of thermal "inertia" and a high thermal insulation such that cooling is substantially retarded.

The provision of a heat store around a pipeline, in accordance with the present invention, can give a thermal capacity per metre of pipeline in the range 500 to 4000 kj/$^{\circ}$K, for example, whereas prior known insulation systems have a thermal capacity of only about 5 to 30 kj/$^{\circ}$K per metre. Thus, whereas with prior known insulation systems, a pipeline will cool down to the temperature at which wax and hydrate form in about 2 to 4 hours, by using the new arrangement described herein, the cooling period can be extended to 72 hours or even more. This will give ample opportunity for process repairs or other remedial work to be executed and eliminate the need for costly line clearance, pigging or other techniques required by premature cooling of the line necessary with other systems. The design of cover or mattress is not critical to the present invention. However, one preferred type of mattress is shown in our patent application PCT/GB900031. It comprises a concrete mat having a tunnel formed in its underside to receive the pipeline therein. We describe in that application the optional provision of heat-insulation material in the tunnel directly around the pipe. In contrast, in the present invention, heat-absorbing material with high heat inertia is

provided next to the pipe, and the insulation is preferably provided by the cover. The heat store may be provided by a continuous bladder which is located within the tunnel or recess below the cover, the bladder having a heat-retaining material, preferably a fluid, therein. This fluid substantially fills the recess and substantially completely encapsulates the exposed portion of the pipeline. Heat carried by the pipeline is transferred to the fluid, and convection causes the complete enclosure to reach a temperature essentially similar to that of the pipeline and little resistance to the flow of heat is provided.

The containment bag stops the warmed material dissipating into the surrounding seawater environment. A variety of different fluids can be used dependent on the exact needs of the overall cooling resistance and insulation requirements. A preferred fluid would be seawater as it has a high thermal capacity and hence high thermal "inertia" and is readily available at the work site. Water has a specific heat of 4.2j/g/°K. Other suitable materials include polymerised seawater, water, waxes, bitumens, thixotropic gels and any other materials which are suited to the intended use and have a high heat capacity, i.e. at least 1.5J/°K.g, most preferably at least 2J/°K.g. Concrete, cement grouts and the like are unsuitable since their heat capacity is only about 0.8 - 1.0 J/°K.g.

The material of the cover should of course provide heat insulation such that, together with the heat capacity in the thermal store, the pipeline will remain at the required temperature for the required extended period. In one preferred embodiment of the invention, a low density aggregate such as "Lytag" concrete may be used as this has low weight with a low thermal conductivity coefficient of between 0.81 - 0.88 w/m^2K°, combined with adequate structural strength. Ordinary concrete can also be used (thermal conductivity about 1.4W/m.°K) as can other materials of thermal conductivity below about 1.5W/m.°K,

provided they are otherwise suitable for this purpose.

Alternative methods by which the heat-retaining material can be constrained within the tunnel or recess can be used to provide the heat store and resist the flow of the fluid to the environment. A stopper such as a block of viscous oil or water-stabilised gel could be set at each end of the cover such that the pipeline penetrate through the block but a sufficient curtain of material is left in place between the pipeline and recess to avoid dissipation of the heat directly to the surrounding seawater by escape of the heat storing fluid from the recess area.

In a further embodiment, the concrete cover may be made so as to act solely as a former. Thus, the recess within the cover has a bladder included and, once the cover is positioned over the pipe, the bladder is filled with a suitable fluid. The fluid has thixotropic properties and thereby any convective heat transfer mechanism is absent. The fluid acts as a heat store. A preferred material is polymerised seawater.

A polymer has been developed which is stable at normal pipeline operating temperatures, and when added to a fluid causes the fluid to act as a solid unless a shear force is induced by an external source. The polymer material has been shown to work with glycol, seawater and fresh water and produces a thermal conductivity of about 0.27 W/m^2K° for the polymerised glycol and 0.54 W/m^2K° for polymeric seawater.

The size of cover, volume of contained material and the choice of polymerised fluid are dependent on the levels of heat retention and insulation sought.

The covers of the invention will preferably either allow pipelines to deflect laterally within the recess and therefore eliminate upheaval buckling phenomena, or constrain the pipeline to overcome any forces generated tending to lift the cover of the invention where an essentially solid store is chosen. In a preferred

embodiment of the invention, the cover which fully restrains the pipeline will be either massive enough to withstand the uplift or will be otherwise held down on the seabed such as by a bund of sand or rock thereover.

In order that the invention may be more fully understood, various embodiments thereof will be described, by way of example only, with reference to the accompanying drawings, wherein:

Figure 1 is a transverse vertical section through a first embodiment of cover and thermal store arranged over a pipeline;

Figure 2 is an axial vertical section of the end of a cover over a pipe, in a second embodiment;

Figure 3 is a transverse vertical section of third embodiment of cover and heat store arranged over a pipeline;

Figures 4A and 4B are schematic transverse vertical sections of a cover over a pipeline with a wax-bitumen filling, according to a fourth embodiment of the invention;

Figure 5 schematically illustrates a series of covers abutting one another to provide continuous protection to a length of pipeline; and

Figure 6 is a transverse section through a pipeline having a heat store coating and a heat insulation coating.

Referring now the the drawings (in which like numerals indicate like parts), Figure 1 shows a concrete cover 1 formed with a tunnel 2 in its underside. The cover 1 is a single elongate concrete member, but it may equally be an articulated mat comprising a plurality of such members as described, for example, in our PCT/GB89/00931. The cover sits on the seabed 3 with the pipeline 4 (to be protected) within the tunnel 2. The pipeline carries hot materials and, in accordance with the present invention, a thermal store material is confined in the tunnel around the pipeline

4. In the embodiment of Figure 1, a fluid thermal store 5 is confined in a flexible bag 6 in the tunnel. The bag and fluid seat around the pipeline to absorb heat therefrom so that the heat store is maintained at the same temperature as the pipeline. The concrete cover acts as a heat insulant to prevent or substantially reduce heat loss from the heat store. In this embodiment, the thermal store is a fluid and remains fluid during its lifetime. This is to be contrasted with cement grout materials whose use as heat insulants is described in PCT/GB89/00931.

In the embodiment shown in Figure 2, the cover 1 may be as shown in Figure 1. However, instead of using a containment bag, the tunnel 2 is plugged with a suitable material such as viscous oil or a gel, and then the closed tunnel filled with thermal store fluid 5. Where a series of covers are in place along a pipeline 4, in end-to-end abutment, each cover can have a plug at each end, or there can be a plug at each end of the series provided that leakage at intermediate abutments is not significant. A viscous thermal fluid can of course be used to reduce leakage from the tunnel.

In the embodiment of Figure 3, the pipeline 4 is covered with a heat-retaining material 8. Over this material 8 is a heat insulating cover 1. In the case when material 8 is fluid and contained within tunnel 2 by a bag or in some other way, it will form around and in contact with the pipeline 1.

Figures 4A and 4B show a way of making one embodiment of the invention. A cover (or series of covers) 1 is provided over a pipeline 4 and the opposed ends of the tunnels in the covers are closed (eg. plugged). One or each cover has an inlet 10 and outlet 11 in its top to permit a filling 12, in this case wax or bitumen for example, to be pumped in to displace the seawater therein. The wax or bitumen filling then serves as a heat-store, and the cover 1 provides heat insulation. Waxes have a specific heat of

about 2.9J/°K.g, and the bitumen is similar. The filling 12 forms closely around the pipeline 1 to ensure good thermal contact.

Figure 5 simply illustrates in plan a series of covers laid in end-to-end abutment over a pipeline.

Figure 6 illustrates in diametrical section a pipeline 4 with a first annular coating of heat-store material 5 and an outer coating of heat-insulation material 13. The outer coating may, for example, be preformed concrete shells.

8. A method according to claim 7, wherein a container bag is provided within the tunnel to contain the heat-retaining material.

9. A method according to claim 7, wherein stoppers are provided in the tunnel to provide chambers therebetween for containing the heat-retaining material.

10. A method according to claim 8, wherein the heat-retaining material is sea-water or polymerised sea-water.

11. A method of reducing the rate of cooling of a subsea pipeline when flow therein is reduced, substantially as herein described with reference to Figure 1, or 2, or 3, or 4, or 5, or 6A and 6B, or 7, or 8, of the accompanying drawings.

12. A subsea installation which comprises a pipeline for flow of hot materials, a heat-retaining material confined adjacent the pipeline to receive heat therefrom in normal flow, and a heat-insulation material outwardly of the heat-retaining material to reduce heat loss therefrom to the surrounding environment, wherein said heat-retaining material is selected from water, seawater, polymerised seawater, bitumen, a thixotropic gel, and other materials having a specific heat capacity of at least 1.5J/°K.g, and said heat-insulation material is selected from concrete and other materials having a thermal conductivity of no more than 1.5W/mK.

13. An installation according to claim 12, which comprises a concrete cover laid over the pipeline, the cover constituting the heat-insulation material, and the heat-retaining material is confined adjacent the pipeline under the cover.

CLAIMS:

1. A method of reducing the rate of cooling of the contents of a subsea pipeline when flow therein is reduced, which comprises confining adjacent the pipeline a heat-retaining material selected from water, seawater, polymerised seawater, wax, bitumen, a thixotropic gel, and other materials having a specific heat capacity of at least 1.5J/°K.g, and providing a heat-insulation material outwardly of the heat-retaining material, the heat-insulation material being selected from concrete and other materials having a thermal conductivity of no more than 1.5W/mK.

2. A method according to claim 1, wherein the heat-retaining material is confined around the pipeline and an outer layer of heat-insulation material applied thereover.

3. A method according to claim 1 or 2, wherein the pipeline is laid in a trench.

4. A method according to claim 1 or 2, wherein the pipeline is covered with a subsea mat or cover.

5. A method according to claim 4, wherein the mat or cover itself constitutes the heat-insulating material.

6. A method according to claim 4 or 5, wherein the mat or cover comprises a concrete cover having a tunnel formed in its underside to receive the pipeline therein.

7. A method according to claim 6, wherein the heat-retaining material is confined in the tunnel adjacent the pipeline.

14. An installation according to claim 13, wherein the heat-retaining material is contained in a flexible bag.

15. A concrete cover for a seabed pipeline, which cover comprises a tunnel in its underside to accommodate the pipeline, wherein the tunnel comprises a flexible elongate container for containing a heat-retaining material therein.

16. A subsea installation substantially as herein described with reference to Figure 1, or 2, or 3, or 4A and 4B, or 5, or 6 of the accompanying drawings.

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